

GaAs Power Amplifier MMIC for GSM single and multiband radios

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Abstract

Power Amplifier MMICs based on GaAs have gained a significant market share in cellular telephones because of their superior performance at low supply voltages. This article presents the new GaAs power amplifier MMIC CGY98 based on MESFET technology for single and dual band radios in ultra small package.

Introduction

In recent years GSM has become the prime standard for wireless communication in Europe as well as in many Asian countries. Whilst handset manufacturers enjoy the ever increasing numbers of subscribers, competition between the manufacture's is getting ever stronger and GSM handsets have passed the milestone of being a commodity product.

Increased stand-by and talk times, further miniaturization and the capability of handling GSM 900 & 1800MHz bands by overall reduced system costs are the driving factors for the new handset generations and mainly influenced by the power amplifier.

SIEMENS as a key supplier of GaAs RF devices to the mobile communication industry reflects this trend by offering a new innovative 3V GaAs power amplifier MMIC solution covering GSM single and dual band applications.

I. Power Amplifier (PA) architectures for GSM dual band applications

The PA architecture for GSM dual band applications is influenced by several key factors. Power Added Efficiency (PAE), harmonic suppression, design ease and flexibility, component count, required PCB space and total system cost are certainly the most important issues to look at before starting the design of the transmit section. The most common principle configurations are shown in Fig. 1. At the first look schematic 1a) reflects the most desired PA dual band configuration providing a single input and a single output covering both frequency bands (900MHz & 1800MHz band). However with such a configuration the PAE is always significant lower (appr. -10%) then for a single band PA because the interstage matchings within the amplifier stages on chip have to be tuned for a wide frequency range. A second possibility is to apply a double peak matching for both frequency bands but production variations of this sophisticated circuits are hard to handle. Both matching solutions cause losses in power gain at each single PA stage. To balance out this effect an extra gain stage or a larger driver stage are required which draws additional current leading to a reduced overall PAE. Furthermore matching and filtering at the PA output becomes highly sophisticated. To apply

one fixed matching circuit at the output is not practicable anymore since the output impedance dramatically changes with frequency and a slight detuning of the matching however results in reduced output power which may violate the GSM specification. Furthermore with one transmit path only we face the problem of the first harmonic generated in the 900MHz band (1st harmonic: $2 \times f_0$) which is directly transformed into the transmit band of GSM1800 and this undesired signal cannot be filtered out. In order to overcome this problem two external matching circuits switched by PIN diodes are an appropriate solution. That helps as well to filter out the harmonics because with two separated transmit paths to the antenna simple low pass filters can be applied. In that case, the losses of switching circuits reduce directly the output power.

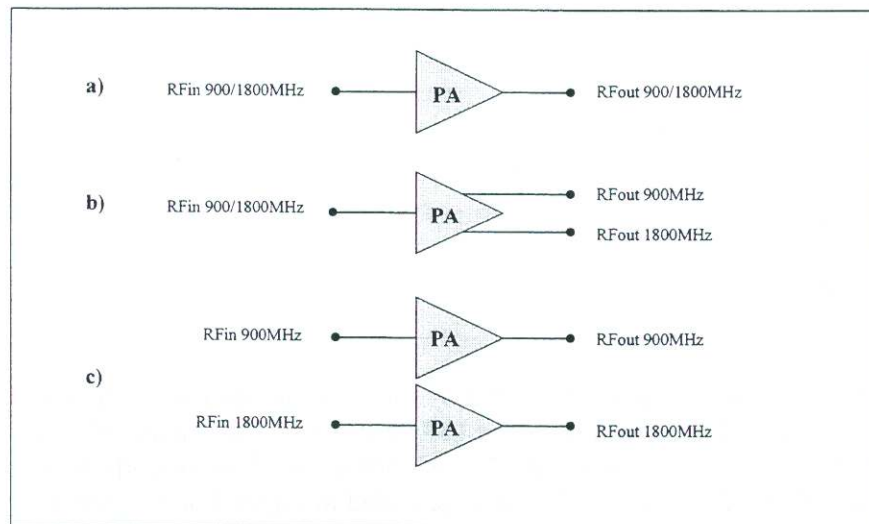


Fig.1: PA architectures for dual band applications

Fig 1b) represents a possible PA dual band architecture with a single input and separated outputs for each frequency band. The reduced PA cost (only one driver stage) and the reduced external component count compared to Fig. 1c) are certainly the main advantages of this concept. By using the same interstage matching for the internal driver stages (both frequency bands 900 & 1800MHz) the same effect of a reduced PAE (appr. -5%) takes place as described above. Internal cross talking at the two separated output stages is very critical and has to be observed during the entire PA MMIC design process.

One of the most convenient PA dual band concept is shown in schematic 1c). It provides a dual input and a dual output PA solution which can be realised either by two separated PA MMICs or an one chip solution with two separated amplifier chains. Using two PA MMICs certainly incorporates a slightly higher component count and extended PCB area then for the other solutions however the increased system performance (PAE), design ease, flexibility and short design cycle time are unbeatable arguments for this concept. Siemens latest product is therefore targeting this concept by providing the PA MMIC CGY98. The CGY98 is a ultra low cost 3V two stage PA MMIC based on GaAs MESFET technology dedicated for GSM900 and GSM1800 applications available in the smallest possible SMD package (SCT-595 \cong SOT-23 derivative) for a GSM class IV amplifier (2W).

II. CGY98 - Single/dual band GSM900/1800 Power Amplifier

Since GSM900 single band mobile phones will continue to keep a strong position in the future Siemens is introducing a new innovative low cost 3V GaAs power amplifier CGY98. This PA is designed to be used as well for GSM1800 and offers therefore maximum flexibility to the circuit designer. To have the same type of PA for both frequency bands in a dual band application is an unique advantage in terms of applying the same control circuit and negative voltage generator for both power amplifier chains.

The CGY98 is a 2-stage PA MMIC (Fig. 2) operating at 3V. In order to spare expensive GaAs die area most matching circuits (input-, interstage- and output matching) have been removed from the chip and needs to be applied externally. The external DC block capacitors are used to fix the transformation line lengths. From a system cost point of view this is much more cost effective than integrating all matching circuits, because you need not more external components. Moreover Q-values of external components (capacitors/inductors) are much better then for integrated components.

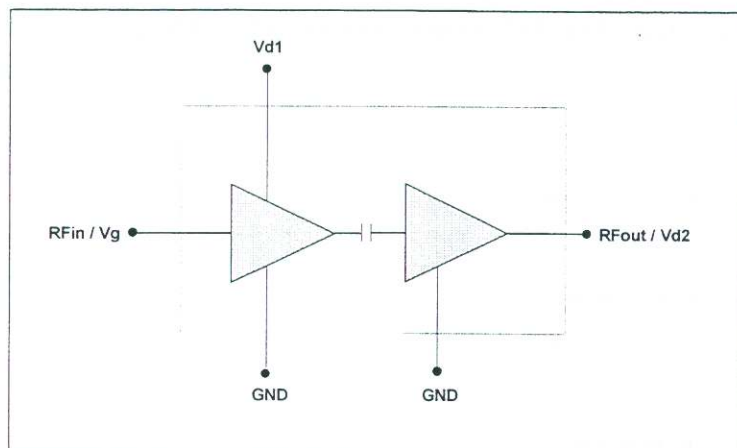


Fig. 2: Schematic of CGY98

The power amplifier is the most critical part of the RF front end by means of determining talk time and stand-by time of the mobile terminal. With a Power Added Efficiency (PAE) of typical 56% at GSM900 band and 48% at GSM1800 frequency band the CGY98 offers excellent performance. Characteristic data of CGY98 at GSM900/1800 frequency bands is provided in Figure 3 and Figure 4:

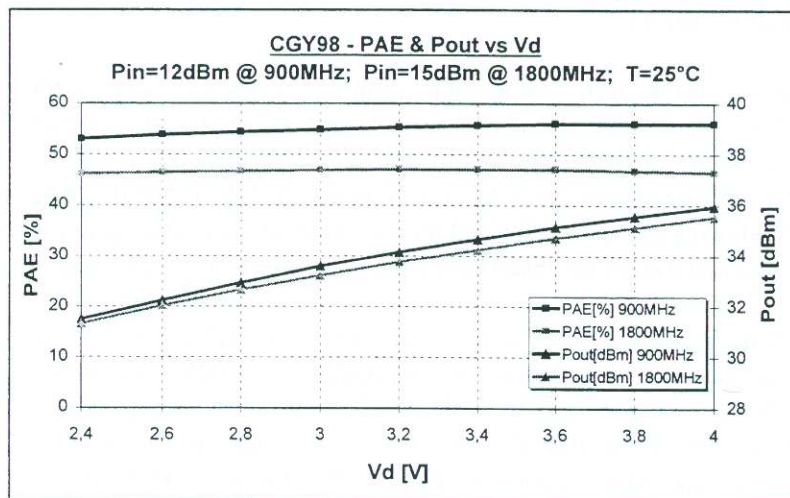


Fig.3: PAE and Pout as a function of supply voltage Vd

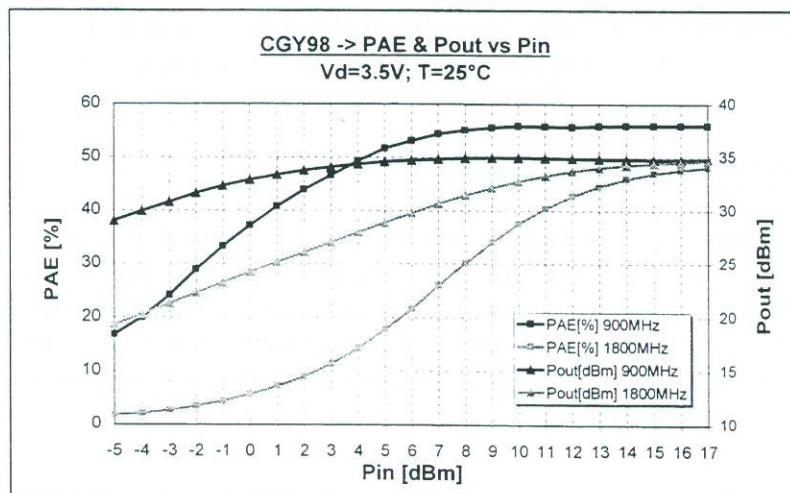


Fig.4: PAE and Pout as a function of input power Pin

The PAE of CGY98 remains constant for wide range of supply voltages at both GSM frequency ranges (900MHz & 1800MHz). From $V_d=4.0V$ down to $V_d=2.8V$ the efficiency (PAE) stays at 56% for GSM900 and 48% for GSM1800. A voltage drop due to discharge of battery in this range does therefore not effect talk- and stand-by time. By means of output power (Pout) above mentioned supply voltage drop is naturally degrading Pout of the PA, however power levels of 33.8dBm (GSM900) and 33.1dBm (GSM1800) are still excellent values at $V_d=3.0V$. Fig.4 shows the dependence of Pout from input power (Pin). CGY98 goes into compression at an input level of appr. 12dBm at 900MHz and appr. 15dBm at 1800MHz. For current systems, where PA input drive levels (Pin) of 0-10dBm are available, CGY98 necessarily needs a driver stage in order to provide the required input power. For that purpose Siemens SIEGET amplifiers BFP420 or BFP450 (depending on required gain and Pin of PA) are appropriate solutions. Both low cost amplifiers can easily be implemented into the transmit paths of each frequency band.

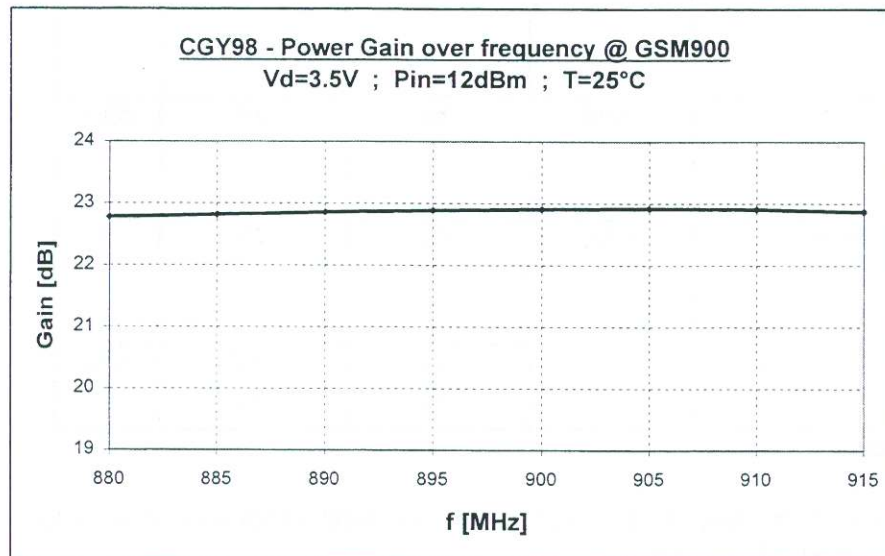


Fig.5: Power gain over frequency @ GSM900

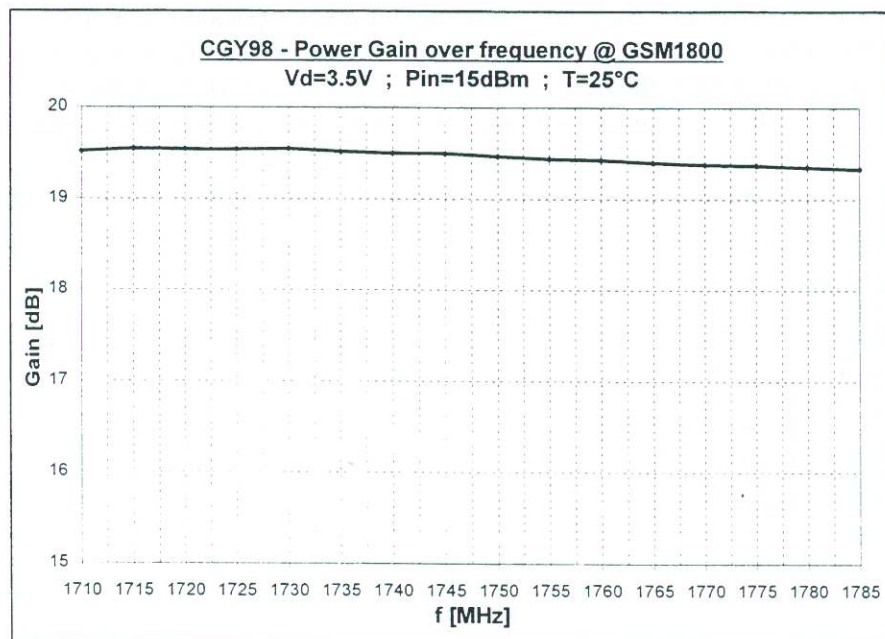


Fig.6: Power gain over frequency @ GSM1800

A very important parameter for a power amplifier is the in-band gain. The in-band gain (GSM900 transmit band: 880MHz – 915MHz; GSM1800 transmit band: 1710MHz-1785MHz) should ideally

remain constant in order to secure required output power level and suppress undesired AM to AM conversion within the PA which could result in spurious signals that violate the GSM specification. The internal amplifier stages of CGY98 have been optimised to provide constant gain over the entire GSM transmit bands. Fig.5 and Fig.6 demonstrate the flatness of power gain over both GSM frequency bands (gain variation of 0.2 to 0.3dB within both GSM bands only). Furthermore CGY98 is designed to be stable over 4:1 VSWR loads. First and second order harmonics are at -42dBc. An overview about most important parameters of dual/single band amplifier CGY98 is featured in Fig.7:

	symbol	900MHz	1800MHz	unit
Supply current Vd=3.5V; Pin=12dBm @ 900MHz Pin=15dBm @ 1800MHz	Id	1.60	1.60	A
Power Gain Vd=3.5V; Pin=12dBm @ 900MHz Pin=15dBm @ 1800MHz	G	23	19	dB
Output Power Vd=3.5V; Pin=12dBm @ 900MHz Pin=15dBm @ 1800MHz	Pout	35	34	dBm
Overall Power Added Efficiency Vd=3.5V; Pin=12dBm @ 900MHz Pin=15dBm @ 1800MHz	PAE	56	48	%
Harmonics				
2fo	-	-42	-42	dBc
3fo	-	-42	-42	dBc

Fig. 7: CGY98 features at a glance

Samples of CGY98 are available from August 98 onwards and dual band application boards for GSM900 and GSM1800 will be provided on request.

One major aspect in doing a RF front-end design for mobile terminals is always package size. For a 4-Watt amplifier like the CGY98 packaging is a major issue as well. A compromise between power dissipation and package size has to be found. Siemens SCT-595 is certainly an optimal balance between both parameters. Since SCT-595 is a standard package which runs in very high production volumes packaging costs are very low compared to other dedicated power packages, which show a relatively low production rate.

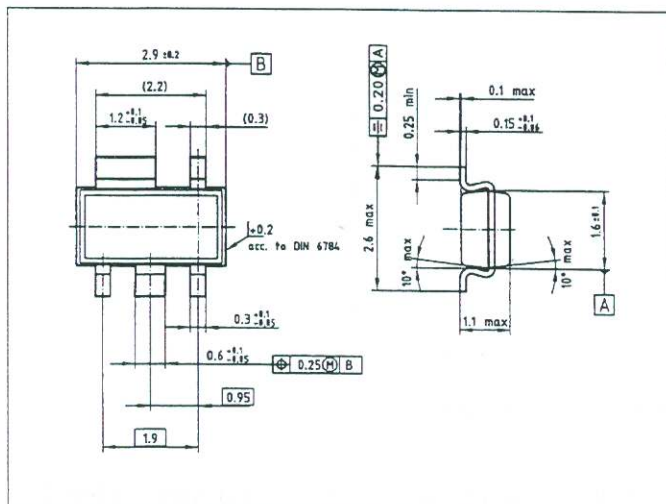


Fig. 8: SCT-595 package outline

By providing 2.9mm x 1.6mm the SCT-595 package (see Fig.8) is currently the smallest power package on the market available for a GSM amplifier. Compared to a TSSOP16, the SCT595 occupies only 1/7 of the PCB board area.

A safe operation with CGY98 at $P_{out} = 4\text{ W}$ in pulsed mode is therefore possible for soldering point temperatures T_s up to 100°C due to very low R_{th} values of die and package. Up to 1.5 W dissipated DC power under CW conditions is no problem.

Conclusion

In order to fulfil high performance, flexibility, time-to-market and cost criteria's of cellular GSM phones, GaAs power amplifier MMICs will be a substantial part of the RF front-end. Siemens is satisfying these requirements by offering an ultra low cost high performance type of single/dual band GSM amplifier CGY98. A single chip dual band amplifier CGY0918 providing two separated amplifier chains will follow soon. PHEMT and HBT technologies will open the door for the next generation of power amplifier MMICs.

Acknowledgement

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